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**SHEET LIKE DISPLAY MEDIUM AND DISPLAY DEVICE**  
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**Application No. 08324096, Filed 19961204, Published 19980619**

**Abstract:** PROBLEM TO BE SOLVED: To provide a color display medium and a color display device with a memory property, rapid responsiveness, flexibility for color display and high picture quality, and with a high alternate characteristic of paper.

**SOLUTION:** A drive circuit 15 applies an electrophoretic layer write-in voltage of positive and negative polarities to a separate electrode group 12 according to an image signal S. An electrophoretic layer 4 having a negative charge is moved to a side applied with a positive voltage, and displays a red color of a diffused medium 4a or a green color of an electrophoretic particle 4b. The drive circuit 15 applies an EC(electrochromic) layer write-in voltage of positive and negative polarities to the separate electrode group 12 according to the image signal S. An EC layer 2 applied with the positive voltage becomes transparent, and the EC layer 2 applied with the negative voltage is colored to a blue color. Thus, image information consisting of the red color, green color, blue color is written in the color display medium 1.

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Title of the Invention: SHEET-LIKE DISPLAY MEDIUM AND  
DISPLAY DEVICE

Application Number: 8-324096

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[Claims]

[Claim 1] A sheet-like display medium, comprising:

an electrochromic layer having a predetermined display area on one surface thereof and exhibiting a transparent region and a colored region based on an electrochromic reaction:

an electrophoretic layer having the predetermined display area on one surface thereof and having a dispersion medium contained in a space therein and a plurality of electrophoretic particles dispersed in the dispersion medium: and

a transparent planar electrode interposed between another surface of the electrochromic layer, opposite to the one surface thereof, and the one surface of the electrophoretic layer.

[Claim 21] A sheet-like display medium according to claim 1, wherein the transparent planar electrode is converted between insulative and conductive by receiving a conversion energy.

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[Claim 3] A sheet-like display medium according to claim 2, wherein the transparent planar electrode is a photoconductive layer which is converted by receiving, as the conversion energy, optical radiation, excluding visible light, such as an ultraviolet ray or an infrared ray.

[Claim 4] A sheet-like display medium according to claim 1, wherein the electrochromic layer comprises, on the one surface thereof, an anisotropic conductive layer, the anisotropic conductive layer being conductive in a thickness direction and not conductive in a two-dimensional direction which is orthogonal to the thickness direction.

[Claim 5] A sheet-like display medium according to claim 1, wherein:

the electrophoretic layer is such that the dispersion medium and the electrophoretic particles have a first color and a second color: and

the electrochromic layer is such that the colored region has a third color.

[Claim 6] A sheet-like display medium according to claim 5, wherein: the electrophoretic layer and the electrochromic layer comprise a combination of red, green and blue as the first to third colors.

[Claim 7] A display device, comprising:

electrochromic display means for displaying a two-dimensional image with a transparent region and a colored region formed according to a predetermined two-dimensional current path pattern: and

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electrophoretic display means laminated with the electrochromic display means for displaying a two-dimensional image with electrophoretic particles moving according to a predetermined two-dimensional electric field pattern so as to allow the image to be observed via the transparent region of the electrochromic display means.

[Claim 8] A display device according to claim 7, wherein the electrochromic display means and the electrophoretic display means display the two-dimensional image in color.

[Claim 9] A display device according to claim 7, wherein the electrochromic display means and the electrophoretic display means display the two-dimensional images to be superimposed on one another.

[Claim 10] A display device according to claim 7, wherein:

the electrochromic display means comprises: an electrochromic layer having a predetermined display area on one surface thereof and exhibiting the transparent region and the colored region based on an electrochromic reaction: a transparent current supply electrode provided on the one surface of the electrochromic layer for supplying to the electrochromic layer a current according to the predetermined two-dimensional current path pattern for exciting the electrochromic reaction: and a transparent planar electrode provided on another surface of the electrochromic layer, opposite to the one surface thereof, and serving as a counter electrode for the current supply electrode: and

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the electrophoretic display means comprises: an electrophoretic layer having the predetermined display area on the first surface thereof and having a dispersion medium contained in a space therein and a plurality of electrophoretic particles dispersed in the dispersion medium: and an electric field application electrode for applying to the electrophoretic layer an electric field according to the predetermined two-dimensional electric field pattern.

[Claim 111 A display device according to claim 10, wherein:

the current supply electrode is a group of individual electrodes arranged in a matrix which are in contact with the one surface of the electrochromic layer and insulated from one another:

the transparent planar electrode is converted between insulative and conductive by receiving a conversion energy:

the electric field application electrode comprises the group of individual electrodes and an electric field planar electrode provided on another surface of the electrophoretic layer opposite to the one surface:

a current according to the predetermined two-dimensional current path pattern flows between the group of individual electrodes and the transparent planar electrode converted to be conductive: and

an electric field according to the two-dimensional electric field pattern is formed between the group of individual electrodes and the electric field planar electrode when the transparent planar electrode is converted to be insulative.

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[Claim 12] A display device according to claim 10, wherein: the electrochromic layer, the transparent planar electrode and the electrophoretic layer are in an integrated sheet-like form and removable from the current supply electrode and the electric field application electrode.

[Claim 13] A display device according to claim 10, wherein: the transparent planar electrode is a photoconductive layer which is converted by receiving, as the conversion energy, optical radiation, excluding visible light, such as an ultraviolet ray or an infrared ray.

[Claim 14] A display device according to claim 10, wherein:

the electrophoretic layer is such that the dispersion medium and the electrophoretic particles have a first color and a second color, respectively: and

the electrochromic layer is such that the colored region has a third color.

[Claim 15] A display device according to claim 14, wherein: the electrophoretic layer and the electrochromic layer comprise a combination of red, green and blue as the first to third colors.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to a sheet-like display medium and a display device using an electrochromic layer and an electrophoretic layer and, more particularly, to a sheet-like display medium

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and a display device capable of multicolor display with a high paper-substituting property.

[0002]

[Prior Art] The development of data processing apparatuses in recent years has greatly improved the productivity of office work, while it also has greatly increased the consumption of paper. This is not desirable in view of the global environment protection. Developments have been taken against this, such as recycling of paper, use of non-wood paper, intensive development of a rewritable sheet-like display medium. While these developments have different objects for different applications, the rewritable sheet-like display medium, among others, has been expected to be valuable as a paper substitute or a new tool, because such a display medium does not require processes such as distribution/regeneration once it is manufactured and distributed to a user.

[0003] Conventionally, the following types have been known as such a sheet-like display medium or a display device.

(A) Those utilizing physical/chemical changes induced by heating/cooling processes so as to switch a material between an uncolored state and a colored (or cloudy) state (e.g., those utilizing a low/high molecular composite material, those utilizing coloring/discoloring of a leuco dye) ("Japan Hardcopy '95, Papers").

(B) Those in which colored particles are moved in a dispersion medium with an applied electric field (e.g.,



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those utilizing electrophoresis) (e.g., Japanese Patent Laid-Open Publication No. 61-86780, Japanese Patent Laid-Open Publication No. 1-267525, Japanese Patent Laid-Open Publication No. 4-345133).

(C) Those in which a cholesteric liquid crystal material is selectively placed into a reflective/transmissive state with an applied electric field (e.g., Japanese Patent Laid-Open Publication No. 7-287214).

(D) Those in which a material is electrochemically colored (utilizing electrochromism) (e.g., Japanese Patent Laid-Open Publication No. 4-37895, "Color Optics Handbook").

[0004]

[Problems to be Solved by the Invention] However, the conventional sheet-like display media or display devices have the following problems. While those of type (A) can easily conduct a 2-color display by utilizing a thermal print head, they are not capable of a high-speed display because the operating principle thereof includes an effect of heating/cooling, and a high display contrast cannot easily be obtained, while it is difficult to conduct a color display. In those of type (B), images can be written only by controlling the applied electric field, so that a high-speed display can be conducted by a two-dimensional driving method, or the like, and the color variation is relatively wide. However, it is difficult to increase the number of colors to be displayed. In those of type (C), images can be written only by controlling the applied electric field, as in those of type (B), so that a high-speed display can be conducted by a



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two-dimensional driving method, or the like, while a color display can also be realized. However, the optical reflection efficiency is poor, whereby only a dark display can be obtained. In order to solve this problem, the device would be complicated and the viewing angle dependency would increase. In those of type (D), a beautiful display color and a wide viewing angle can be advantageously obtained. However, it is difficult to increase the number of colors to be displayed. If a multi-color display is to be conducted, a good display property and a memory property can be obtained only for certain colors.

[0005] Thus, an object of the present invention is to provide a sheet-like display medium and a display device with a memory property, a high-speed response property, a high image quality, and a high paper-substituting property. A further object of the present invention is to provide a sheet-like display medium and a display device with a memory property, a high-speed response property, a color display accommodating property, a high image quality, and a high paper-substituting property.

[0006]

[Means for Solving the Problems] In order to achieve these objects, the present invention provides a sheet-like display medium, comprising: an electrochromic layer having a predetermined display area on one surface thereof and exhibiting a transparent region and a colored region based on an electrochromic reaction: an electrophoretic layer having the predetermined display area on one surface thereof and having a dispersion medium contained in a space therein and a plurality of

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electrophoretic particles dispersed in the dispersion medium: and a transparent planar electrode interposed between another surface of the electrochromic layer opposite to the one surface thereof and the one surface of the electrophoretic layer. With such a structure, images can be displayed by the electrochromic layer and the electrophoretic layer, whereby it is possible to provide a memory property of retaining the display state after the power is turned off. Moreover, by employing a group of individual electrodes arranged in a matrix and a planar electrode as an electrode combination, it is possible to conduct matrix two-dimensional driving, whereby image data can be written to the sheet-like display medium at a high speed so as to provide a good high-speed response property. Furthermore, with the combination of the electrochromic layer and the electrophoretic layer, it is possible to conduct a clear display and thereby to obtain high-quality images. Thus, the paper-substituting property is increased by providing the memory property, the high-speed response property and the high image quality.

[0007] In order to obtain these objectives, the present invention also provides a display device, comprising: electrochromic display means for displaying a two-dimensional image with a transparent region and a colored region formed according to a predetermined two-dimensional current path pattern: and electrophoretic display means laminated with the electrochromic display means for displaying a two-dimensional image with electrophoretic particles moving according to a predetermined two-dimensional electric field pattern so as to allow the image to be observed via the transparent re-

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gion of the electrochromic display means, With such a structure, images can be displayed by the electrochromic display means and the electrophoretic display means, whereby it is possible to provide a memory property of retaining the display state after the power is turned off. Moreover, by employing a group of individual electrodes arranged in a matrix and a planar electrode as an electrode combination, it is possible to conduct matrix two-dimensional driving, whereby image data can be written to the sheet-like display medium at a high speed so as to provide a good high-speed response property. Furthermore, with the combination of the electrochromic display means and the electrophoretic display means, it is possible to produce a clear display and thereby to obtain high-quality images. Thus, the paper-substituting property is increased by providing the memory property, the high-speed response property and the high image quality.

[0008]

[Embodiments of the Invention] A display device according to an embodiment of the present invention will now be described in detail with reference to the Figures. The display device includes a sheet-like display medium for conducting a multicolor display and a driver for driving the sheet-like display medium.

[0009] Figure 1 is a cross-sectional view illustrating a structure of the sheet-like display medium. The sheet-like display medium 1 comprises: an electrochromic layer (hereinafter, referred to as the "EC layer") 2 having a predetermined display area and exhibiting a transparent region and a colored region (e.g., a blue region) by an

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electrochromic reaction based on a voltage/current control: an electrophoretic layer 3 having the same display area as that of the EC layer 2 and exhibiting a first colored region (e.g., a red region) and a second colored region (e.g., a green region) of colors different from that of the colored region of the EC layer 2 by controlling an applied electric field: and a transparent intermediate layer 4 interposed between the EC layer 2 and the electrophoretic layer 3. A transparent anisotropic conductive layer 5 is formed on an observed side A of the EC layer 2, and a supporting substrate 6 of a plastic, or the like, is provided on a non-observed side B of the electrophoretic layer 3. The sheet-like display medium 1 is capable of displaying, on the observed side A, multiple colors including red, green, blue and mixed colors thereof.

[0010] The EC layer 2 is formed in a space kept by a spacer 7A between the intermediate layer 4 and the anisotropic conductive layer 5. For example, a **WO<sub>3</sub>-type** electrochromic material consisting of three layers, which are sequentially formed on the observed side A, of an amorphous tungsten oxide (a-WO<sub>3</sub>), tantalum pentoxide (**Ta<sub>2</sub>O<sub>5</sub>**) and an iridium oxide (**IrO<sub>x</sub>**) may be used for the EC layer 2. When a negative voltage is applied to the **WO<sub>3</sub>** side, an electron and an ion are injected into **WO<sub>3</sub>**, and transparent **WO<sub>3</sub>** is reduced into a blue tungsten bronze (**H<sub>x</sub>WO<sub>3</sub>**) as a colored region, thereby coloring the **WO<sub>3</sub>-type** electrochromic material in blue. The colored state is retained after the voltage is removed, and is erased only by applying an inverse voltage so as to oxidize the blue **H<sub>x</sub>WO<sub>3</sub>** back to transparent.

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[0011] The electrophoretic layer 3 is formed in a space kept by a spacer 7B between the intermediate layer 4 and the supporting substrate 6, and has a plurality of electrophoretic particles 3b dispersed in a dispersion medium 3a. The dispersion medium 3a may be an insulative organic solvent, such as an isoparaffin-type hydrocarbon, hexylbenzene, tetrafluorodibromoethane, perfluoropolyether or toluenetrifluoride, mixed with a red dye and an ionic surfactant for controlling an electric charge on the surface of the electrophoretic particles 3b. The polarity of the electrophoretic particles 3b is determined by the ionic surfactant. Herein, the surface of the electrophoretic particles 3b are negatively charged. The electrophoretic particles 3b may be particles obtained by dispersing a green pigment in a polyethylene wax. When an electric field is applied to the electrophoretic layer 3, the negatively charged electrophoretic particles 3b move toward the side to which a positive voltage is applied, thereby displaying the red of the dispersion medium 3a or the green of the electrophoretic particle 3b. The display state is retained after the voltage is removed, and is erased only by applying an inverse voltage.

[0012] The intermediate layer 4 is obtained by coating a transparent ultraviolet conductive layer 4b such as tin oxide which changes from insulative to conductive using ultraviolet radiation, over the entire surface of a transparent polyethylene film 4a on the observed side A. An end portion 4c of the intermediate layer 4, including the film 4a and the conductive layer 4b, is slightly exposed from the EC layer 2 and the electrophoretic layer 3 for electrical connection to a driver 10

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which will be described later. The ultraviolet conductive layer 4b may be another member which is converted between insulative and conductive by receiving a conversion energy, e.g., a photoconductive layer which is converted from insulative to conductive by optical radiation, excluding visible light, such as an infrared ray. The EC layer 2 and the electrophoretic layer 3 can be sequentially driven basically with a pair of electrodes by appropriately converting between insulative and conductive based on the presence/absence of optical radiation.

[0013] Figure 2 is a plan view illustrating the anisotropic conductive layer 5. The anisotropic conductive layer 5 is obtained by dispersing a plurality of conductive particles 5b in a film 5a. The portion of the anisotropic conductive layer 5 where the conductive particles 5b exist has a conduction anisotropy wherein the portion is conductive in the thickness direction thereof due to a conduction effect and is not conductive in a two-dimensional direction which is orthogonal to the thickness direction. As the anisotropic conductive layer 5 is provided on the observed side A, the film may be a transparent plastic, and the conductive particle 5b may be obtained by coating a transparent conductive film, such as a transparent conductive layer of indium tin oxide, or the like, on the surface of a transparent particle of glass, plastic, or the like. In such a case, it is preferable for preventing images from being skewed that the transparent film 5a and the transparent conductive particles 5b have substantially the same refractive index.



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[0014] Figure 3 is a cross-sectional view illustrating a structure of the driver. The driver 10 has a case 11 of a transparent plastic, or the like. The case 11 has an attachment cavity 11a for attachment of the sheet-like display medium 1, and an abutting portion 11b for positioning the sheet-like display medium 1. The attachment cavity 11a includes a group of individual electrodes 12, which are transparent and are arranged in a matrix, and a planar electrode 13 provided on the inner surface thereof so as to oppose each other. The attachment cavity 11a includes an insertion hole 110 provided on the bottom side thereof into which the end portion 4c of the intermediate layer 4 is inserted. The insertion hole 110 includes a connection terminal 14 which can be connected to the ultraviolet conductive layer 4b of the intermediate layer 4. The driver 10 includes a driving circuit 15 for driving the sheet-like display medium 1, a switch 16 for controlling the connection potential for the planar electrode 13, and an ultraviolet irradiation apparatus 17 for irradiating the ultraviolet conductive layer 4b with an ultraviolet ray. A driving line 18a connected to the group of individual electrodes 12 and a grounded earth line 18b are provided to extend from the driving circuit 15. The earth line 18b is connected to the connection terminal 14 and the planar electrode 13 via the switch 16, respectively,

[0015] The group of individual electrodes 12 includes a plurality of individual electrodes 12b made of a transparent conductive film of iridium tin oxide (ITO), or the like, which are arranged in a matrix via a transparent insulative region 12a. The group of individual elec-



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trodes 12 is driven by a thin film transistor using a polysilicon.

[0016] The driving circuit 15 acts on the sheet-like display medium 1 in synchronism with the ultraviolet irradiation apparatus 17. When the ultraviolet irradiation apparatus 17 is ON, a DC voltage according to an input image signal S is applied to the group of individual electrodes 12 so as to supply a current to the EC layer 2, thereby displaying transparent and blue. When the ultraviolet irradiation apparatus 17 is OFF, a DC voltage according to the input image signal S is applied to the group of individual electrodes 12 so as to apply an electric field through the electrophoretic layer 3, thereby displaying red and green.

[0017] Next, an operation of the present display device will be described.

### (1) Attachment of Sheet-Like Display Medium 1 to Driver 10

Figure 4 is a cross-sectional view illustrating a display state of the display device. An operator attaches a new sheet-like display medium 1, or a sheet-like display medium 1 which needs to be rewritten, as illustrated in Figure 1, to the driver 10, as illustrated in Figure 4. In particular, the sheet-like display medium 1 is attached into the attachment cavity 11a, with the anisotropic conductive layer 5 of the sheet-like display medium 1 facing the group of individual electrodes 12, until the sheet-like display medium 1 abuts the abutting portion 11b. The anisotropic conductive layer 5 contacts the group of individual elec-

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trodes 12, and the supporting substrate 6 contacts the planar electrode 13. As the anisotropic conductive layer 5 contacts the group of individual electrodes 12, the anisotropic conductive layer 5 and the group of individual electrodes 12 are put into a conductive state by the conduction anisotropy of the anisotropic conductive layer 5.

### [0018] (2) Writing Image Data to Electrophoretic Layer 3

First, the switch 16 is closed, and the ultraviolet irradiation apparatus 17 is turned OFF, so that the ultraviolet conductive layer 4b is put into an insulative state. When the image signal S is externally input, the driving circuit 15 applies to the group of individual electrodes 12 an electrophoretic-layer-writing-voltage of the positive or negative polarity, e.g., +50 V, -50 V, according to the image signal S. The electrophoretic layer 3 is supplied with a voltage according to a partial voltage of the electrophoretic layer 3, the intermediate layer 4 and the EC layer 2. As shown in Figure 4, since the surface of the electrophoretic particle 3b is negatively charged, the electrophoretic particles 3b located between the individual electrodes 12b, to which a positive voltage is applied, and the planar electrode 13 migrate in the dispersion medium 3a to gather on the side of the individual electrodes 12b. The electrophoretic particles 3b located between the individual electrodes 12b, to which a negative voltage is applied, and the planar electrode 13 migrate in the dispersion medium 3a to gather on the side of the planar electrode 13. From the observed side A, the green electrophoretic particles 3b are seen in areas where the electrophoretic particles 3b have gathered due to the

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applied positive voltage, thereby presenting a green display state. On the other hand, the red dispersion medium **3a** is seen in areas where the electrophoretic particles **3b** have gone away due to the applied negative voltage, thereby presenting a red display state.

### [0019] (3) Writing Image Data to EC Layer 2

When the write operation to the electrophoretic layer 3 is completed, the switch 16 is opened, and the ultraviolet irradiation apparatus 17 is turned ON, so that the ultraviolet conductive layer 4b becomes conductive. When the image signal S is externally input, the driving circuit 15 applies to the group of individual electrodes 12 an EC-layer-writing-voltage of the positive or negative polarity, e.g., +3 V, -3 V, according to the image signal S. By the action of the anisotropic conductive layer 5, the applied voltage is transferred directly to the EC layer 2. Thus, a circuit is formed in which a current flows from the group of individual electrodes 12, through the EC layer 2, to the ultraviolet conductive layer 4b. Areas of the EC layer 2 become transparent where the positive voltage is applied to the individual electrodes **12b**, and other areas of the EC layer 2, where the negative voltage is applied to the individual electrodes **12b**, are colored in blue as blue tungsten bronze ( $H_xWO_3$ ) **2a** is formed on the observed side A. When the write operation to the EC layer 2 is completed, the ultraviolet irradiation apparatus 17 is turned OFF. During this operation, the electrophoretic layer 3 for which the write operation has previously been completed is isolated from a circuit, but keeps displaying the still image for a long period of time without a power due to its memory property. By these op-

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erations, image data consisting of red, green, blue and mixed colors thereof is written to the sheet-like display medium 1. Thus, on the observed side A, the red or green of the electrophoretic layer 3 is seen in areas where the EC layer 2 is transparent, while blue is seen regardless of the color of the electrophoretic layer 3 in areas where the EC layer 2 is blue. Since the display state is retained after the voltage is removed, the sheet-like display medium 1 can retain the display after the sheet-like display medium 1 is removed from the driver 10, as illustrated in Figure 5.

### [0020] (4) Erasing Image Data

An inverse voltage of the EC-layer-writing-voltage written to the group of individual electrodes 12 is applied, while the sheet-like display medium 1 to which the image data has been written is being attached to the driver 10. The blue tungsten bronze ( $H_xWO_3$ ) 2a of the EC layer 2 is oxidized back to transparent  $WO_3$ , thereby erasing the image data written to the EC layer 2. Then, the switch 16 is closed, and an inverse voltage of the electrophoretic-layer-writing-voltage written to the group of individual electrodes 12 is applied. The electrophoretic particles 3b of the electrophoretic layer 3 go back to the dispersed state, thereby erasing the image data written to the electrophoretic layer 3.

[0021] The above-described display device provide the following effects. By employing the planar electrode 13 and the group of individual electrodes 12 arranged in a matrix as an electrode combination, it is possible to conduct matrix two-dimensional driving, whereby image can be written to the sheet-like display

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medium 1 at a high speed only by an electrical control. Therefore, a good high-speed response property can be provided. Moreover, with the combination of the electrophoretic layer 3 for displaying the first color (red) and the second color (green) and the EC layer 2 for displaying transparent and the third color (blue), a 3-color display can be performed. Furthermore, half tone mixed colors can easily be displayed by changing the display area proportion among the respective colors. Thus, a good color display accommodating property can be provided. Moreover, with the combination of the EC layer 2 and the electrophoretic layer 3, it is possible to conduct a clear multicolor display and thereby to obtain high-quality images. Furthermore, since images are displayed by the EC layer 2 and the electrophoretic layer 3, there is provided a memory property of retaining the display state after the power is turned off, and the sheet-like display medium 1 can be used repeatedly. As a result, it is possible to reduce the power consumption for displaying images. Moreover, by employing the anisotropic conductive layer 5, an applied voltage can be transferred directly to the EC layer 2 or the electrophoretic layer 3, thereby producing a high resolution image with a minimum applied voltage and thus reducing the power consumption. Furthermore, since the sheet-like display medium 1 has the memory property, the high-speed response property, the color display accommodating property, the high image quality and the low power consumption property, the paper-substituting property is increased, thereby contributing to global environment protection. Moreover, since the displayed images can be viewed from the observed side A while the sheet-like display medium 1 is attached to the driver 10, the in-

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ventive arrangement can be used as a display. Furthermore, since the sheet-like display medium 1 is not provided with a group of electrodes in a matrix or linear arrangement, the sheet-like display medium 1 can be produced using a simple and inexpensive structure, thereby reducing the cost for producing a plurality of still images. Moreover, since the dispersion medium 3a and the electrophoretic particles 3b of the electrophoretic layer 3 are colored with a dye or a pigment, the color variation is wide, and it is possible to easily select any two desired colors.

[0022] The present invention is not limited to the above-described embodiments, as various other embodiments may be possible. For example, when the inventive arrangement does not have to be used as a display, the case 11 and the group of individual electrodes 12 may be made of an opaque material. Moreover, the case 11 may be of a type which can be flipped open like a book or a binder,

[0023]

[Effects of the Invention] As described above, according to the present invention, images are displayed by the electrochromic layer and the electrophoretic layer, thereby providing a memory property of retaining the display state after the power is turned off. Moreover, by employing the group of individual electrodes arranged in a matrix and the planar electrode as an electrode combination, it is possible to conduct matrix two-dimensional driving, so that an image can be written to the sheet-like display medium at a high speed, thereby providing a good high-speed response property. Further-



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more, with the combination of the electrochromic layer and the electrophoretic layer, it is possible to conduct a clear display and thereby obtain high-quality images. Therefore, by providing the memory property, the high-speed response property and the high image quality, the paper-substituting property is increased, thereby contributing to global environment protection. Moreover, with the combination of the electrophoretic layer for displaying the first color and the second color and the electrochromic layer for displaying a transparent state and the third color, a 3-color display can be performed. Furthermore, half tone mixed colors can easily be displayed by changing the display area proportion among the respective colors. Therefore, a good color display accommodating property can be provided. Thus, by providing the memory property, the high-speed response property, the color display accommodating property and the high image quality, the paper-substituting property is increased, thereby contributing to global environment protection.

[Brief Description of the Drawings]

[Figure 1] A cross-sectional view illustrating a structure of a sheet-like display medium according to the present invention.

[Figure 2] A front view of an anisotropic conductive layer according to the present invention.

[Figure 3] A cross-sectional view illustrating a structure of a driver according to the present invention.



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[Figure 41 A cross-sectional view illustrating a display state of a display device according to the present invention.

[Figure 51 A cross-sectional view illustrating a display state of the sheet-like display medium according to the present invention.

[Description of the Reference Numerals]

- 1 Sheet-like display medium
- 2 Electrochromic layer (EC layer)
- 2a Tungsten bronze ( $\text{H}_x\text{WO}_3$ )
- 3 Electrophoretic layer
- 3a Dispersion medium
- 3b Electrophoretic particle
- 4 Intermediate layer
- 4a Polyethylene film
- 4b Ultraviolet conductive layer
- 4c End portion
- 5 Anisotropic conductive layer
- 5a Film
- 5b Conductive particle
- 6 Supporting substrate
- 7A, 7B Spacer
- 10 Driver
- 11 Case
- 11a Attachment cavity
- 11b Abutting portion
- 11c Insertion hole
- 12 Group of individual electrodes
- 12a Insulative region
- 12b Individual electrode
- 13 Planar electrode

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14 Connection terminal

15 Driving circuit

16 Switch

17 Ultraviolet irradiation apparatus

18a Driving line

18b Earth line

A Observed side

B Non-observed side

S Image signal

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[Abstract]

[Problems] To provide a color display medium and a color display device with a memory property, a high-speed response property, a color display accommodating property, a high image quality, and a high paper-substituting property.

[Means for Solving the Problems] A driving circuit 15 applies to a group of individual electrodes 12 an electrophoretic-layer-writing-voltage of a positive or negative polarity according to an image signal S. A negatively charged electrophoretic layer 4 moves to the side to which a positive voltage is applied, thereby displaying a red of a dispersion medium 4a or a green of electrophoretic particle 4b. The driving circuit 15 applies to the group of individual electrodes 12 an EC-layer-writing-voltage of a positive or negative polarity according to the image signal S. Areas of an EC layer 2 applied with a positive voltage become transparent, and other areas of the EC layer 2 applied with a negative voltage are colored in blue. Image data consisting of red, green and blue is written to a color display medium 1.